

CONDITIONED REINFORCEMENT AND DISCRIMINATION IN SECOND-ORDER SCHEDULES

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Pigeons were exposed to multiple second-order schedules in which responding on the "main key" was reinforced according to either a variable-interval or fixed-interval schedule by production of a brief stimulus on the "brief-stimulus key". A response was required to the brief stimulus during its fourth (final) presentation to produce food; responses to the earlier brief stimuli indicated the extent to which the final brief stimulus was discriminated from preceding ones. Main-key response rates were higher in early components of paired brief-stimulus schedules, in which each brief stimulus was the same as that paired with reinforcement, than in comparable unpaired brief-stimulus or tandem schedules. Poor discrimination occurred between paired brief stimuli (Experiment I). When chain stimuli on the main key induced a discrimination between the first two and second two brief stimuli, the response-rate enhancement in the paired brief-stimulus schedule persisted (Experiment II). Rate enhancement diminished when the initial link of the chain included the first three components (Experiment IV). Eliminating the contingency between responding and brief-stimulus production also diminished rate enhancement (Experiment III). The results show that the discriminative and conditioned reinforcing effects of food-paired brief stimuli may be selectively manipulated and suggest that the reinforcing effects are modulated by other reinforcers in the situation.

Key words: conditioned reinforcement, second-order schedule, brief-stimulus presentations, chain schedule, multiple schedule, tandem schedule, key peck, pigeons

Second-order schedules have been used in a number of studies to investigate the conditioned reinforcement effectiveness of various stimuli. Kelleher (1966) defined a second-order schedule as "one in which the behavior specified by a schedule contingency is treated as a unitary response that is itself reinforced according to some schedule of primary reinforcement" (p. 181). For example, consider a schedule in which food is presented after completion of four successive fixed-interval 60-sec (FI 60-sec) schedules. Here, the completion of each FI 60-sec schedule is treated as a unitary response that is itself reinforced according to a fixed-ratio 4 (FR 4) schedule of primary reinforcement. In the terminology of second-order schedules (*cf.* Gollub, 1977; Kelleher, 1966) this schedule is denoted as

FR 4 (FI 60-sec). If no stimulus changes occur at the end of each component, such a second-order schedule is called a tandem schedule. It is possible, however, to schedule the occurrence of brief stimuli at the end of each component. If such stimuli also occur at the end of the final component—immediately preceding food—they are referred to as paired brief stimuli; if they occur at the end of all components *except* the last they are called unpaired brief stimuli (since they are not "paired" with food).

Some studies that have compared the effects of presenting paired brief stimuli with the effects of presenting unpaired brief stimuli have found behavior to be better maintained by the paired brief-stimulus schedules (Byrd and Marr, 1969; de Lorge, 1971; Malagodi, De Weese, and Johnston, 1973). Stubbs (1971), however, found equivalent effects of paired and unpaired brief stimuli; both were able to maintain a pattern of responding within components similar to that maintained by primary reinforcement. Stubbs (1971) argued further that some of the studies that reported conditioned reinforcement effects for paired

¹This research was supported by NIMH Grant MH-20752 to the University of California, San Diego. We thank Nancy Squires for her help in the early stages of the research and Timothy Bryson, who conducted the first experiment as part of a senior honors thesis. Reprints may be obtained from either author, Department of Psychology C-009, University of California at San Diego, La Jolla, California 92093.

brief stimuli relative to unpaired brief stimuli did not control adequately for differences between the number and type of the paired and unpaired stimuli used. De Lorge (1971) controlled for these factors, however, by reversing the stimulus used for the paired stimulus with that used for the unpaired stimulus. He found higher overall rates of responding and shorter postreinforcement pauses with paired brief stimuli.

The appropriateness of interpreting a rate enhancement as evidence for conditioned reinforcement has been questioned by Squires, Norborg, and Fantino (1975), who showed that birds do not appear to discriminate well between the components of a second-order schedule. They used a procedure in which brief stimuli occurred on a second ("brief-stimulus") key, and a response to the terminal paired brief stimulus was required to obtain food. Responses to earlier brief stimuli were unnecessary, or in one experiment were punished, and yet the birds consistently responded to all brief stimuli. Squires *et al.* (1975) suggested that when rate enhancements are observed in second-order schedules they may be due to the poor discrimination between the component immediately preceding food and the prior components of the schedule. In other words, the brief-stimulus presentations may weaken temporal control in second-order schedules, resulting in higher main-key response rates (more appropriate to rates during the final component) independent of any conditioned reinforcement effect.

Squires *et al.* did not find higher main-key response rates in their paired brief-stimulus schedules than in unpaired brief-stimulus schedules in which the brief stimulus at the end of the last component was omitted. However, this result may have reflected a procedural asymmetry between the two types of schedules employed. In the unpaired brief-stimulus schedules, a response on the main key at the end of the last component immediately occasioned a food presentation. In the paired brief-stimulus schedules, though, main-key responses were temporally separated from food presentation by the occurrence of a brief stimulus and a required response to that stimulus (the reinforced response). This difference may have enhanced responding in the unpaired brief-stimulus schedules relative to that in the paired schedules, thus masking

some rate enhancement. To control for this possibility, the present study equated response requirements for each of three types of schedules: tandem, paired brief-stimulus, and unpaired brief-stimulus. Moreover, we employed multiple (*mult*) second-order schedules, since it was likely that they would optimize the likelihood of finding differences between response rates in paired and unpaired brief-stimulus schedules. This expectation was based not only on the greater sensitivity of multiple schedules, as opposed to single schedules (*cf.* Nevin, 1973), but also on the fact that de Lorge's (1971) experiment showing higher response rates on paired than on unpaired schedules compared these schedules within the context of a multiple schedule. As in the Squires *et al.* (1975) experiment, the present study employed keylight brief stimuli and a discrimination measure. Whereas Squires *et al.* studied FR (FI) schedules, the present study examined both *mult* FR (FI) and *mult* FR (VI) schedules. Thus, our aim was to determine whether rate enhancement effects would occur in *mult* FR brief-stimulus schedules with either FI or VI components and, if so, the extent to which these could be attributed to conditioned reinforcement, on the one hand, and to a lack of discrimination between components on the other.

EXPERIMENT I

In Experiment I, the three basic schedules (tandem, unpaired brief-stimulus, paired brief-stimulus) were compared, two at a time, in multiple schedules. The goal was first to establish whether rate enhancement would indeed be observed in the paired brief-stimulus schedule.

METHOD

Subjects

Three male White Carneaux pigeons were maintained at approximately 80% of their free-feeding weights. All had experience with two-key procedures.

Apparatus

A standard experimental chamber was employed, measuring 31 by 31 by 38 cm. On the front wall of the chamber were mounted two translucent Gerbrands response keys, 10

cm apart and 21 cm above the floor. The left key could be illuminated red, green, yellow, or orange, and the right key white or blue. Either key could be operated by depressing it with a force of approximately 0.15 N. Also in the front wall of the chamber, and 5 cm above the floor, was a solenoid-operated hopper for grain presentation. Illumination of the chamber was provided by a miniature 6-W lamp and white noise was used to mask extraneous sounds. The adjacent room contained standard relay programming equipment.

Procedure

Figure 1 illustrates the sequence of events and the consequences of responses in the two-key procedures employed. In the paired and unpaired brief-stimulus schedules, responding on the left key produced, on either a VI 1-min schedule (for Pigeons 1804 and 6448) or an FI 1-min schedule (for Pigeon 6254), a brief stimulus, *i.e.*, illumination of the right key for 2 sec, and advancement to the next component of the second-order schedule. After completion of four such components, a response on the right key during the brief-stimulus period resulted in illumination of the food magazine and 4 sec access to grain.

In the paired brief-stimulus schedule, the color of the first three brief stimuli was the same as that of the brief stimulus paired with food. In the unpaired brief-stimulus schedule, the first three brief stimuli were of a different color from the one paired with primary reinforcement.

In the tandem schedule, left-key responses during the first three components were followed only by advancement to the next component, unsignalled by any exteroceptive stimulus (*i.e.*, the right key remained unlit). The component schedule was a VI 1-min schedule for two pigeons (1804 and 6448) and an FI 1-min for Pigeon 6254. In the fourth component, however, a left-key response did occasion a brief-stimulus presentation on the right key, during which a response on that key produced grain reinforcement. The purpose of including a terminal brief stimulus in all schedules, to which a response was required in order to obtain food, was to maintain identical response requirements for primary reinforcement.

In every schedule, the houselight remained lit at all times except during food presentation and the left ("main") key was illuminated

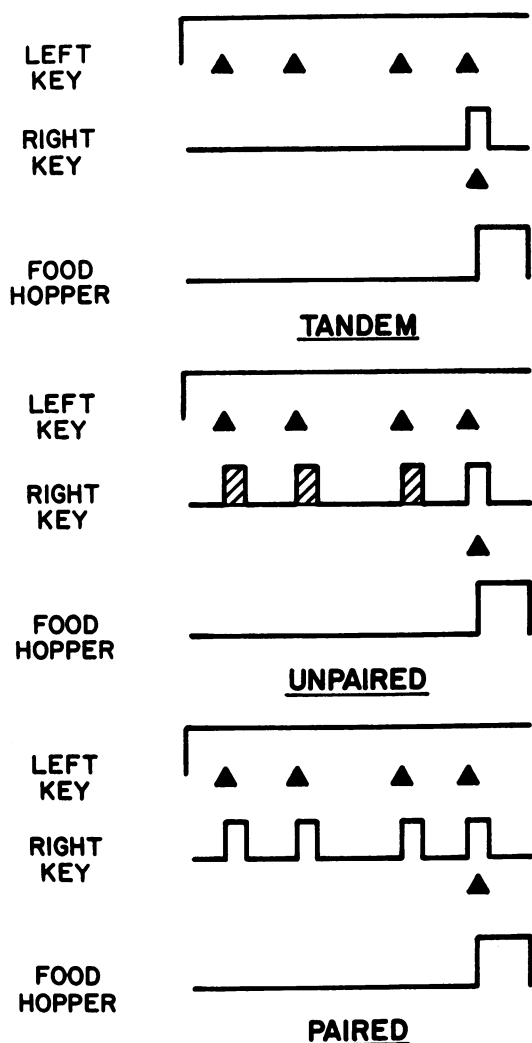


Fig. 1. Schematic diagram illustrating the sequence of events in the tandem, unpaired, and paired brief-stimulus schedules. Time progresses from left to right, and deflections of the lines indicate operation of the keylights and hopper (times not drawn to scale). Right-keylight line deflections with shading under them represent brief stimuli unpaired with reinforcement; those without shading denote paired brief stimuli. Triangles below the left-keylight line indicate effective responses on that key, *i.e.*, responses that advanced the subject to the next component and/or produced a brief stimulus. Responses were effective at times determined by the component schedule, which was either a VI 1-min or FI 1-min for a given subject. Triangles below the right-keylight line show that responses on that key during the terminal brief stimulus immediately activated the hopper.

throughout the session. Right-key ("brief-stimulus key") responses during brief stimuli occurring in the first three components of any

schedule or at any time when the key was dark had no scheduled consequences but were recorded. If primary reinforcement was not obtained at the end of the fourth component, the component was repeated until food was obtained. This rarely happened, however. Daily sessions were conducted six days a week, each session lasting until 20 reinforcers were obtained.

The experiment consisted of four conditions, designed to include all possible comparisons between the tandem, paired, and unpaired brief-stimulus schedules. During the first condition, the tandem and paired brief-stimulus schedules were presented alternately in a multiple schedule. The main-key color differed for the two second-order schedules. This key was yellow in the paired brief-stimulus schedule and green in the tandem schedule for all pigeons. The color of the paired brief stimulus was the same in the two schedules; it was blue for Pigeons 1804 and 6448 and white for Pigeon 6254. Pigeons 1804, 6448, and 6254 received 23, 26, and 20 sessions, respectively, of exposure to this condition.

Next, the paired and unpaired brief-stimulus schedules were combined in a multiple schedule, with the main key red in the unpaired brief-stimulus schedule and again yellow in the paired brief-stimulus schedule. The paired brief stimulus was blue and the unpaired brief stimulus white for Pigeons 1804 and 6448. For Pigeon 6254, the paired brief-stimulus color was white and the unpaired brief-stimulus blue. All pigeons were exposed to this condition for 20 sessions.

In the third condition, a multiple schedule of paired and unpaired brief-stimulus schedules was presented, as in the second condition, but with the main key colors reversed for all subjects. That is, the main key was now red in the paired brief-stimulus schedule and yellow in the unpaired brief-stimulus schedule. In addition, the brief-stimulus colors were reversed for two of the pigeons (1804 and 6448); the paired brief stimuli were changed to white and the unpaired brief stimuli were blue. Pigeon 1804 received 18 sessions of exposure to this condition, Pigeon 6448 received 19 sessions, and Pigeon 6254 received 20 sessions.

Finally, in Condition 4, a multiple schedule was introduced in which tandem and unpaired brief-stimulus schedules alternated. For

all subjects, the main key was green in the tandem schedule and yellow in the unpaired brief-stimulus schedule. The paired brief stimuli were blue for Pigeons 1804 and 6448 and white for Pigeon 6254. The unpaired brief stimuli were white for Pigeons 1804 and 6448 and blue for Pigeon 6254. Pigeon 1804 remained on this schedule for 24 sessions; Pigeons 6448 and 6254 each had 31 sessions of exposure.

RESULTS

Performance differences between schedules were evaluated statistically by means of a Wilcoxon rank sum test (one-tailed). Only those differences that were significant beyond the $p = 0.05$ level were judged reliable and are reported below (without repeating the statistical information).

The upper panels of Figure 2 show the main-key response rates from Condition 1 (paired brief-stimulus *versus* tandem). It can be seen that, for all pigeons, response rates increased throughout the interreinforcement interval. Moreover, there was a substantially higher rate of responding in the first component of the paired brief-stimulus schedule than in the tandem schedule for Pigeons 6448 and 6254. This rate enhancement disappeared in succeeding components, and by the third component, these pigeons responded faster in the tandem schedule. A possible reason for this reversal (across components) is discussed below. The only (statistically) significant difference evidenced for Pigeon 1804 was a slight rate enhancement in the tandem over the paired brief-stimulus schedule in the fourth component.

The rate enhancement observed in the early portions of the paired brief-stimulus schedule was also reflected in the average length of the postreinforcement pause, as shown in the second row of Figure 2. Whereas the response-rate data showed a clear rate enhancement in the first component for only two of the three subjects, all pigeons paused considerably longer under the tandem than the paired brief-stimulus schedule.

Data concerning the discriminability of components in the paired brief-stimulus schedule are presented in the bottom panels of Figure 2. This figure shows only responses when the brief-stimulus key was lit, since virtually no brief-stimulus key responses were made when the brief-stimulus key was dark. Each point

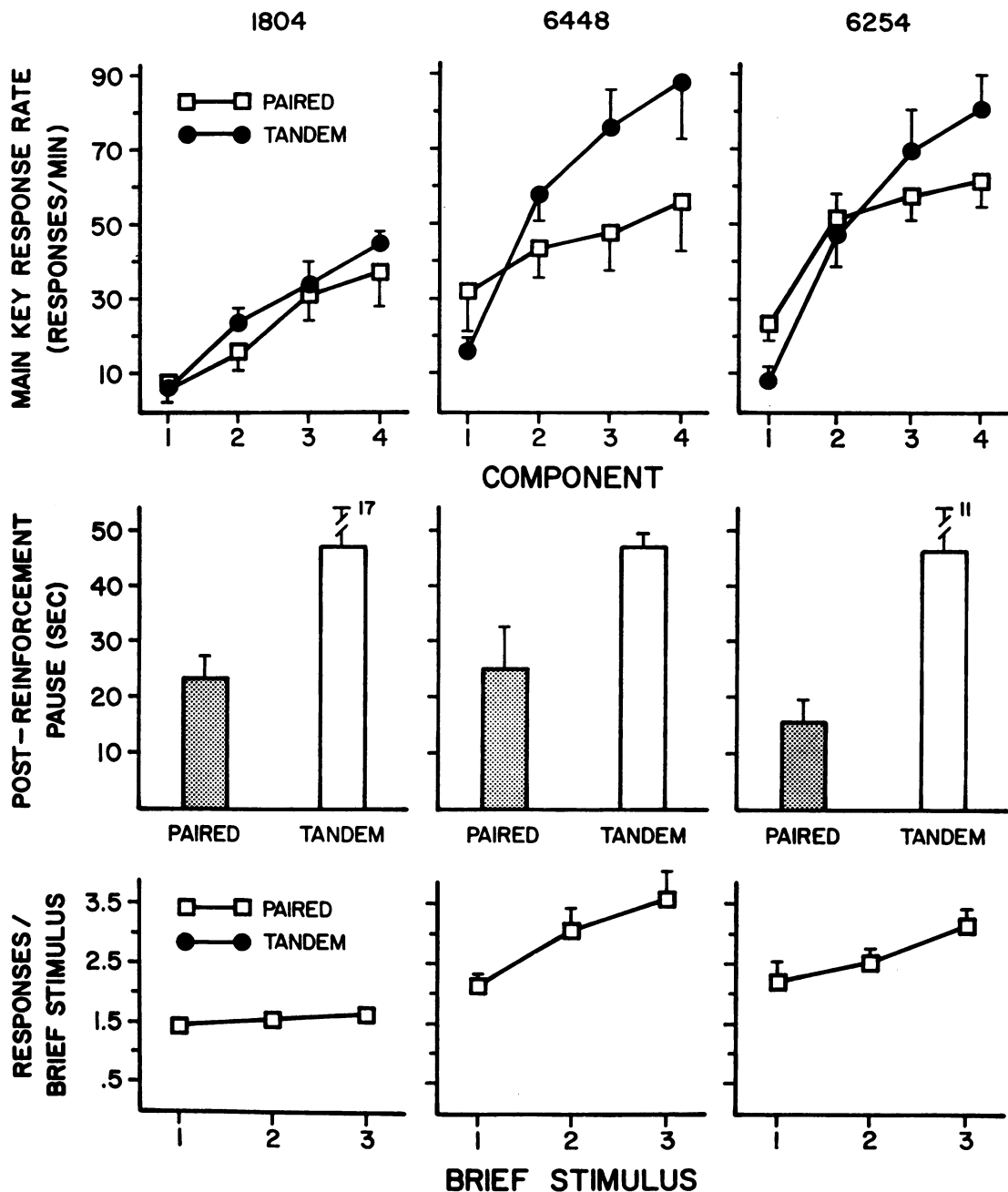


Fig. 2. Main-key response rates, postreinforcement pauses, and brief-stimulus key responses per brief-stimulus presentation for the paired brief-stimulus versus tandem condition. Data represent averages over five sessions; vertical bars denote one standard deviation (bars are omitted if they end within a data symbol).

was obtained by computing the average number of right-key responses emitted during each brief stimulus. The average number of responses to the fourth brief stimulus was necessarily equal to one because the first response immediately activated the grain hopper. The

average number of responses per brief stimulus increased across the first three components for every pigeon, and practically every brief stimulus was responded to, regardless of its position. This latter finding was also confirmed by a counter that recorded the number of brief

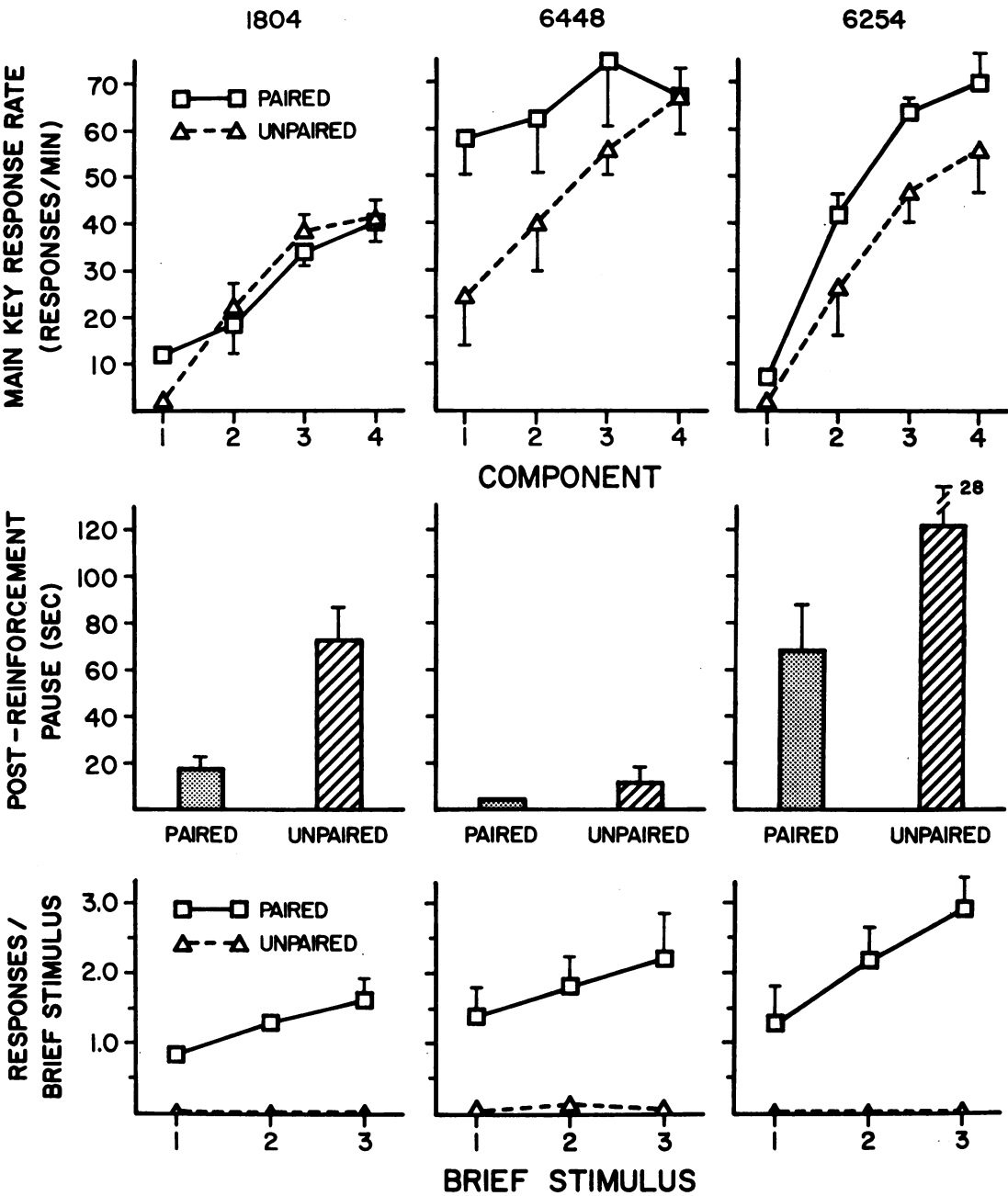


Fig. 3. Main-key response rates, postreinforcement pauses, and brief-stimulus key responses per brief-stimulus presentation for the first exposure to the paired brief-stimulus versus unpaired brief-stimulus condition. Data represent averages over five sessions; vertical bars denote one standard deviation (bars are omitted if they end within a data symbol).

stimuli that received at least one response, and rarely was this less than the total number of paired brief stimuli.

Figures 3 and 4 present the results from Conditions 2 and 3, which both involved a

comparison between paired and unpaired brief-stimulus schedules. The paired brief-stimulus schedule maintained a much higher rate of responding in the first component for all pigeons. This difference disappeared or be-

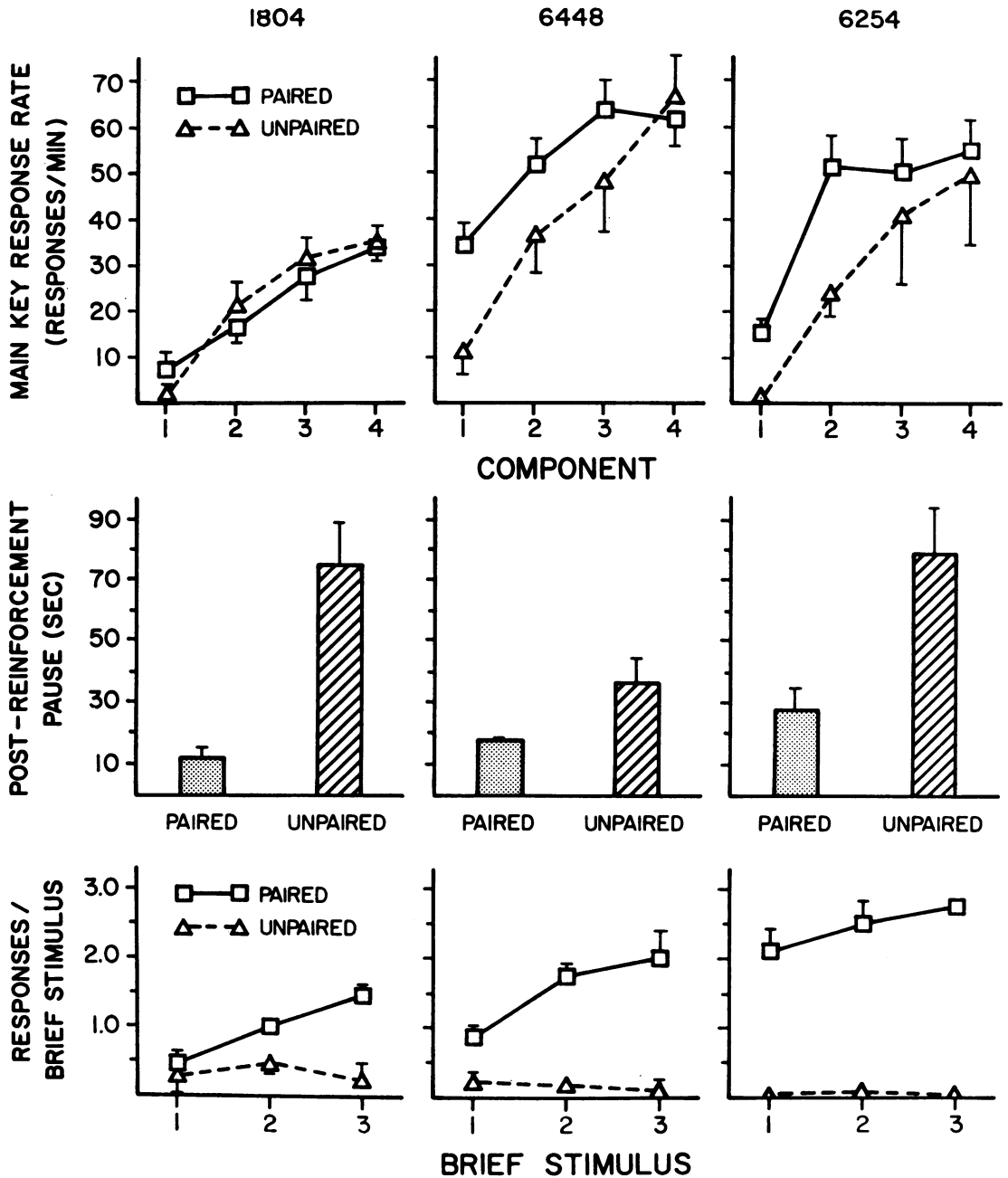


Fig. 4. Main-key response rates, postreinforcement pauses, and brief-stimulus key responses per brief-stimulus presentation for the second exposure to the paired brief-stimulus *versus* unpaired brief-stimulus condition. Data represent averages over five sessions; vertical bars denote one standard deviation (bars are omitted if they end within a data symbol).

came unreliable by the fourth component in every case. (For Pigeon 6254, the difference in the fourth component was significant on the first exposure but was not significant in the

replication.) The characteristics of responding under the paired and unpaired brief-stimulus schedules seemed generally unaffected by the key-color reversal between Conditions 2 and 3,

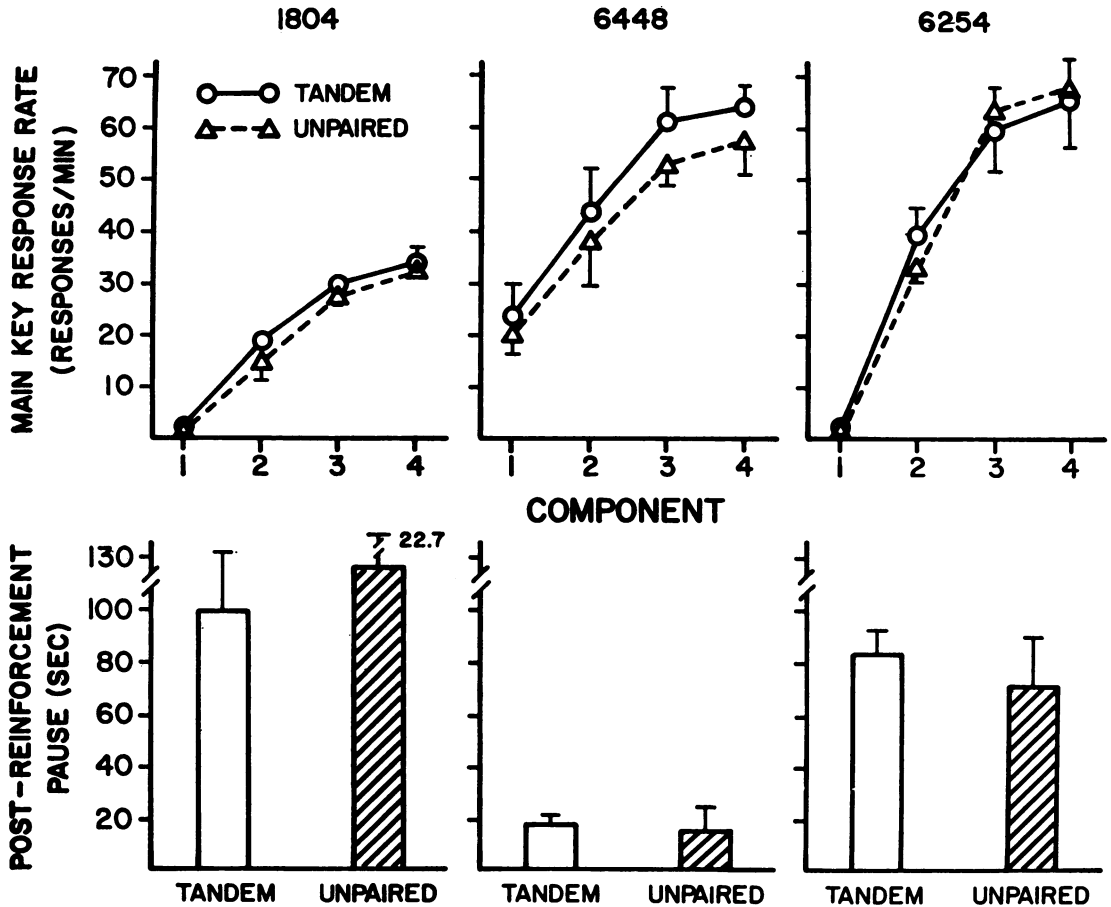


Fig. 5. Main-key response rates and postreinforcement pauses for the tandem *versus* unpaired brief-stimulus condition. Data represent averages of five sessions; vertical bars denote one standard deviation (bars are omitted if they end within a data symbol). All unbroken error bars are drawn using the same scale as that in the unbroken portion of the ordinate.

indicating that preference between the colors employed was a relatively unimportant factor in these schedules.

The postreinforcement pause data are shown in the middle panels of Figures 3 and 4. There was consistently less pausing in the paired than in the unpaired brief-stimulus schedule for all three pigeons.

The bottom rows of Figures 3 and 4 present the discrimination data for the paired and unpaired brief-stimulus schedules. The unpaired brief stimuli received virtually no responses in Condition 2, whereas the paired brief stimuli almost always averaged at least one response. The number of pecks was an increasing function of the time since the last reinforcement. In Condition 3, after the brief-stimulus colors were reversed for Pigeons 1804 and 6448, they

continued to emit a substantial number of responses to what was formerly the paired brief stimulus, although not as many as to the stimulus currently paired with food.

The results from Condition 4, involving the tandem and unpaired brief-stimulus schedules, are displayed in Figure 5. The average rate of responding on the main key is shown as a function of schedule components in the upper panels of Figure 5. The response rates did not differ significantly between the two schedules, except for a slight enhancement under the tandem schedule in Component 1 for Pigeon 1804, in Component 4 for Pigeon 6448, and in Component 2 for Pigeon 6254. The postreinforcement pause data (middle row, Figure 5) show no systematic difference between the schedules.

Few pecks occurred on the darkened right key in the tandem schedule, so no discrimination data were graphed. Also, few responses occurred to the right key in the unpaired brief-stimulus schedule at those times when it was dark. The pigeons showed near-perfect discrimination between the brief-stimulus colors, with few responses emitted to the first three brief stimuli.

Cumulative recordings taken from the preceding conditions showed the presence of a scalloped pattern of responding during much of the paired schedule, in the case of Pigeon 6254 (whose schedule had FI 1-min components). No consistent within-component patterning was observed in either the tandem or unpaired brief-stimulus schedules.

DISCUSSION

The main results from Experiment I may be summarized as follows: food-paired brief stimuli, presented contingent on responding, maintained higher initial response rates and shorter postreinforcement pauses than unpaired brief-stimulus or tandem schedules. Terminal response rates tended to be highest for the tandem schedule, although in a direct comparison the tandem and unpaired brief-stimulus schedules were nearly equivalent in terms of the responding they maintained. With respect to the initial component, response-rate enhancement in the paired brief-stimulus schedule, these findings agree with the previous work of de Lorge (1971). He compared tandem and unpaired brief-stimulus schedules with paired brief-stimulus schedules, using illumination of the food opening as a brief stimulus, and found higher rates of responding and shorter pauses in the paired brief-stimulus schedule than in either of the other schedules. The generality of these findings is extended by the present study, in which the brief stimuli involved keylight changes only. It is likely that the failure of the Squires *et al.* (1975) study to replicate these results was due to the procedural asymmetry, noted above, regarding the response requirements in the schedules employed, or to their use of simple rather than multiple schedules.²

One could interpret the present results as support for the claim that paired brief stimuli act as conditioned reinforcers. There remains, however, the somewhat puzzling observation that response rates in the later components of

the tandem schedule were often elevated over those in the paired brief-stimulus schedule. It is conceivable that this resulted from the fact that in the paired brief-stimulus schedule, the pigeons invariably turned away from the main key during brief-stimulus periods to respond on the other key. Such an interruption, which did not occur in the tandem schedule, may have influenced responding on the main key.

An alternative, and not necessarily contradictory, explanation rests on the suggestion by Squires *et al.* that the paired brief stimuli disrupt temporal control, such that pigeons do not discriminate well between components of the second-order schedule. Responding in the initial and final components should therefore resemble one another more in the paired brief-stimulus schedule than in either of the other schedules, resulting in a response-rate enhancement in the early components but not in the later components. Also consistent with this explanation was the observation that the birds responded to the early paired brief stimuli well before food was available.

Two implications of the temporal control interpretation contrast it from the conditioned reinforcement hypothesis. First, there should be a correlation between the degree of discrimination shown toward successive paired brief stimuli and the amount of rate enhancement seen in responding on the main key. Thus, if pigeons could be trained to master the discrimination between successive brief stimuli, *i.e.*, withhold responses to the early ones, they should no longer show a rate enhancement in the early portions of the paired brief-stimulus schedule relative to the unpaired brief-stimulus or tandem schedules. The conditioned reinforcement view, on the other hand, would not preclude independent discriminative and reinforcing functions for the brief stimuli, so that one could be manipulated without affecting the other. There is some evidence in the present experiment favoring the latter position, in that the two subjects showing the clearest rate enhancement

²Additional subjects were studied under simple second-order schedules: the comparisons between tandem, paired, and unpaired brief-stimulus schedules paralleled closely the present findings. Therefore, it seems unlikely that the use of multiple schedules was entirely responsible for the discrepancy between the Squires *et al.* findings and those of the present experiment.

in the paired brief-stimulus schedule (Pigeons 6448 and 6254) also showed the most discrimination between successive brief stimuli (shown in the steeper gradients in the graphs of responses per brief stimulus, Figures 2 to 4). A within-subject analysis of Pigeon 1804's behavior supports this observation, in that the increase in discriminability between paired brief stimuli in Condition 2 (lower-left panel, Figure 2) compared to that in Condition 1 (lower-left panel, Figure 3) was accompanied by the emergence of a rate enhancement in the paired brief-stimulus schedule. This is the opposite of what the temporal control hypothesis would have predicted. A more direct test of this implication was performed in Experiment II.

A second test between the two theories involves the effects of removing the dependency between responding and production of a brief stimulus. The temporal control hypothesis, as stated above, would predict the same results regardless of whether brief stimuli were response-dependent; the brief stimuli paired with food should interfere with temporal control. The conditioned reinforcement hypothesis, however, clearly implies that the rate enhancement in the paired brief-stimulus schedule should vanish on removal of the dependency, and overall responding should drop, analogous to the decline in responding seen in food-reinforcement schedules when the response-reinforcer dependency is abolished (Zeiler, 1968).

The next experiments investigated the extent to which the above factors influence responding in second-order schedules, so that the merits of the two hypotheses could be more readily evaluated.

EXPERIMENT II

In Experiment II, a procedure was implemented to induce a discrimination between the early and late brief stimuli in the schedules previously used. This was accomplished by creating a chain schedule on the main key in a manner analogous to that of Squires *et al.* (1975). They showed that color cues were effective in controlling brief-stimulus key responding. In the experiment described below, an attempt was made to replicate that result as well as to observe the effects on main-key responding. If the rate enhancement in the

paired brief-stimulus schedule were completely dependent on the lack of discrimination between brief stimuli, then no rate enhancement should occur with the chain schedule. The concept of conditioned reinforcement might then be unnecessary in analyzing the performance under second-order schedules.

METHOD

Subjects and Apparatus

The same subjects and apparatus were used as in Experiment I.

Procedure

Experiment II was composed of three conditions analogous to three conditions of Experiment I. Comparisons were made between schedules including either paired brief stimuli, unpaired brief stimuli, or none but a terminal brief stimulus. The primary reinforcement contingencies were identical in all schedules to those in Experiment I. Responding on the main key was followed according to either an FI 1-min or VI 1-min schedule by advancement to the next component (as well as a brief stimulus appropriate to the schedule) and a peck on the right key during the final brief stimulus occasioned food. The only difference between the schedules employed in this experiment and in Experiment I was that the main-key color changed approximately halfway through each schedule. At the onset of the second brief stimulus, or at the time a response was made to advance the pigeon to the third component (in the case of the tandem schedule), the main-key color changed to a new color and remained that color until primary reinforcement was obtained. Thus, the schedules consisted of a two-component chain schedule superimposed on a four-component second-order schedule. The chain schedule with paired brief stimuli presented at the end of every component will be termed the "chain + paired" schedule. The schedule with unpaired brief stimuli occurring at the end of the first three components and a terminal paired brief stimulus will be referred to as the "chain + unpaired" schedule. The chain schedule in which a brief stimulus occurred only at the end of the fourth component will be called simply the "chain" schedule. The chain + paired schedule was procedurally similar in one sense to the un-

paired brief-stimulus schedule of Experiment I, in that the basis was provided for a conditional discrimination between the earlier and later brief stimuli. The difference is that in the case of the unpaired brief-stimulus schedule, the color of the brief stimulus itself provided the basis for discrimination, whereas in the chain + paired schedule the brief stimuli were all identical and it was the main-key color that indicated which stimuli were predictive of food.

The following comparisons were performed by combining the above schedules, two at a time, in a multiple schedule: (1) chain + paired *versus* chain; (2) chain + unpaired *versus* chain + paired; and (3) chain + unpaired *versus* chain. The order of exposure to the three conditions was the same for all pigeons. The key colors, component schedules, and number of sessions spent in each condition are shown in Table 1.

RESULTS

As in Experiment I, the results were analyzed statistically with a Wilcoxon rank sum test. Again, all differences noted below were significant beyond the $p = 0.05$ level. Figure 6 shows the results from Condition 1 for all subjects. Response rates were elevated in the chain + paired schedule over those in the chain schedule during the first and second components for all pigeons. For Pigeon 6254, this rate difference persisted into the later components, whereas the difference disap-

peared in these components for Pigeons 1804 and 6448.

The postreinforcement pause data, shown in the middle panels of Figure 6, are consistent with the response-rate results. All pigeons showed shorter pauses in the schedule with paired brief stimuli presented contingent on responding. This was true whether or not the components of the second-order schedules were VI 1-min or FI 1-min schedules, although the absolute length of the pause was much longer with the FI 1-min components (middle-right panel).

The third row of graphs in Figure 6 presents the discrimination data for the chain + paired schedule. The average number of brief-stimulus key responses during each of the brief stimuli is shown as a function of brief-stimulus position. Introducing the chain schedule on the main key was apparently effective in inducing a discrimination between the earlier and later brief stimuli, with the former receiving far fewer responses. The discrimination was clearest with Pigeons 1804 and 6448, which responded to only about one in 10 of the initial brief stimuli. Pigeon 6254, in contrast, emitted many responses to even the first two brief stimuli. The chain manipulation was of some impact, however, as shown by a comparison with the discrimination data of Experiment I (lower-right panels, Figures 2 to 4).

The response-rate results from the Condition 2 comparison between chain schedules

Table 1

Component schedules, key colors, and number of sessions conducted for each subject and experimental condition in Experiment II.

Condition	Subject	Second-Order Schedule Components	Main-Key Color Sequence		Brief-Stimulus Colors		Number of Sessions
			<i>Chain</i>	<i>Chain+Paired</i>	<i>Paired</i>	<i>Unpaired</i>	
Chain <i>vs</i> Chain+Paired	1804	VI 1-min	Green Yellow	Red Orange	Blue	White	34
	6448	VI 1-min	Green Yellow	Orange Red	Blue	White	39
	6254	FI 1-min	Red Orange	Yellow Green	White	Blue	34
			<i>Chain+Unpaired</i>	<i>Chain+Paired</i>			
Chain+Unpaired <i>vs</i> Chain+Paired	1804	VI 1-min	Green Yellow	Red Orange	Blue	White	18
	6448	VI 1-min	Green Yellow	Orange Red	Blue	White	18
	6254	FI 1-min	Red Orange	Yellow Green	White	Blue	18
			<i>Chain+Unpaired</i>	<i>Chain</i>			
Chain+Unpaired <i>vs</i> Chain	1804	VI 1-min	Green Yellow	Red Orange	Blue	White	19
	6448	VI 1-min	Green Yellow	Orange Red	Blue	White	20
	6254	FI 1-min	Orange Red	Yellow Green	White	Blue	10

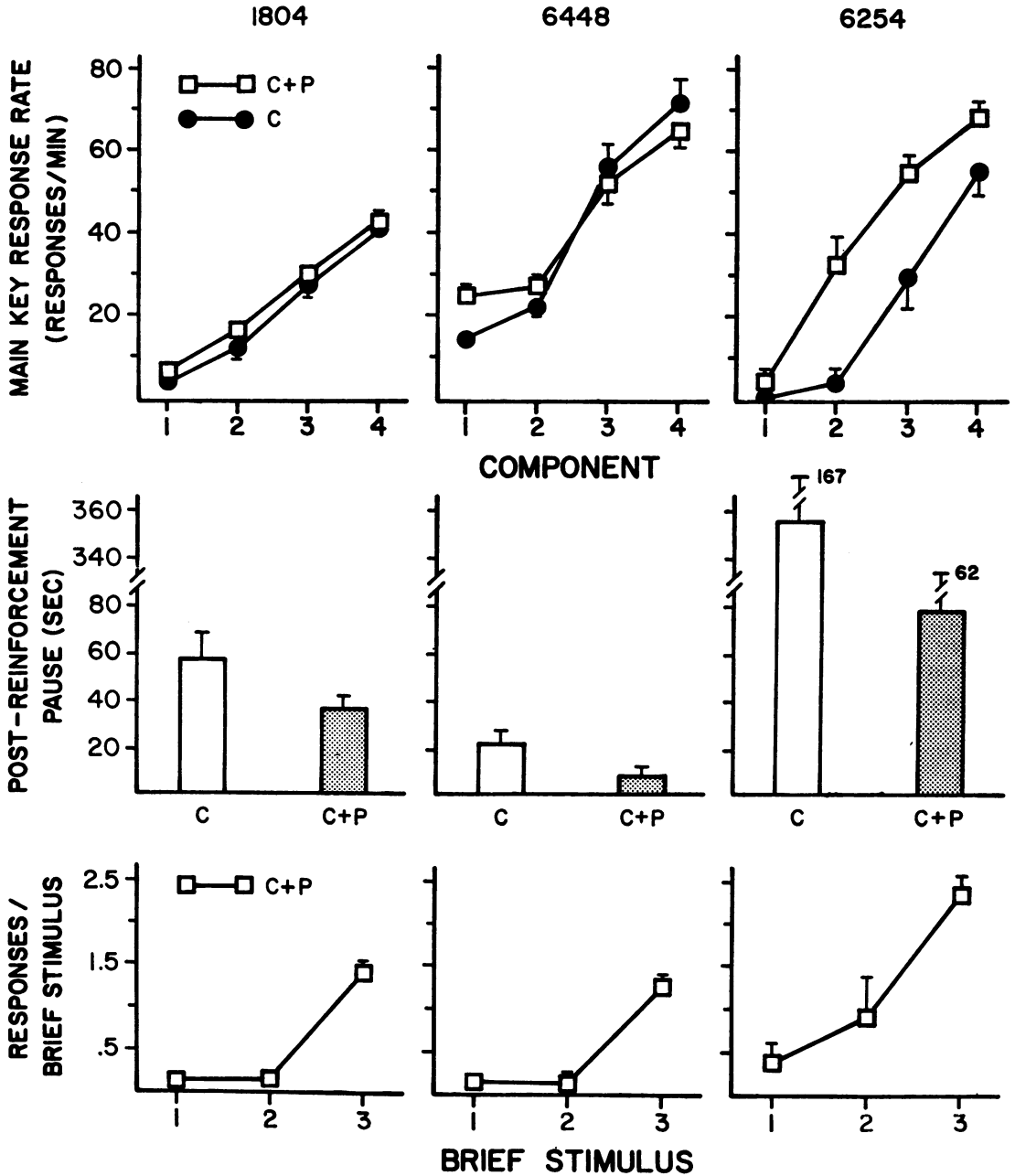


Fig. 6. Main-key response rates, postreinforcement pauses, and brief-stimulus key responses per brief-stimulus presentation for the chain (C) versus chain + paired (C+P) condition. Data represent averages over five sessions; vertical bars denote one standard deviation (bars are omitted if they end within a data symbol). All unbroken error bars are drawn using the same scale as that in the unbroken portion of the ordinate.

containing either paired or unpaired brief stimuli are depicted in Figure 7 (top row). The results bear a great resemblance to the previous results in Condition 1. All pigeons showed a rate enhancement in the first two components of the chain + paired schedule.

This difference persisted into the third component in the case of Pigeon 6254 but disappeared by the fourth component. The enhancement vanished by the third component with the other two subjects.

The second row of graphs in Figure 7

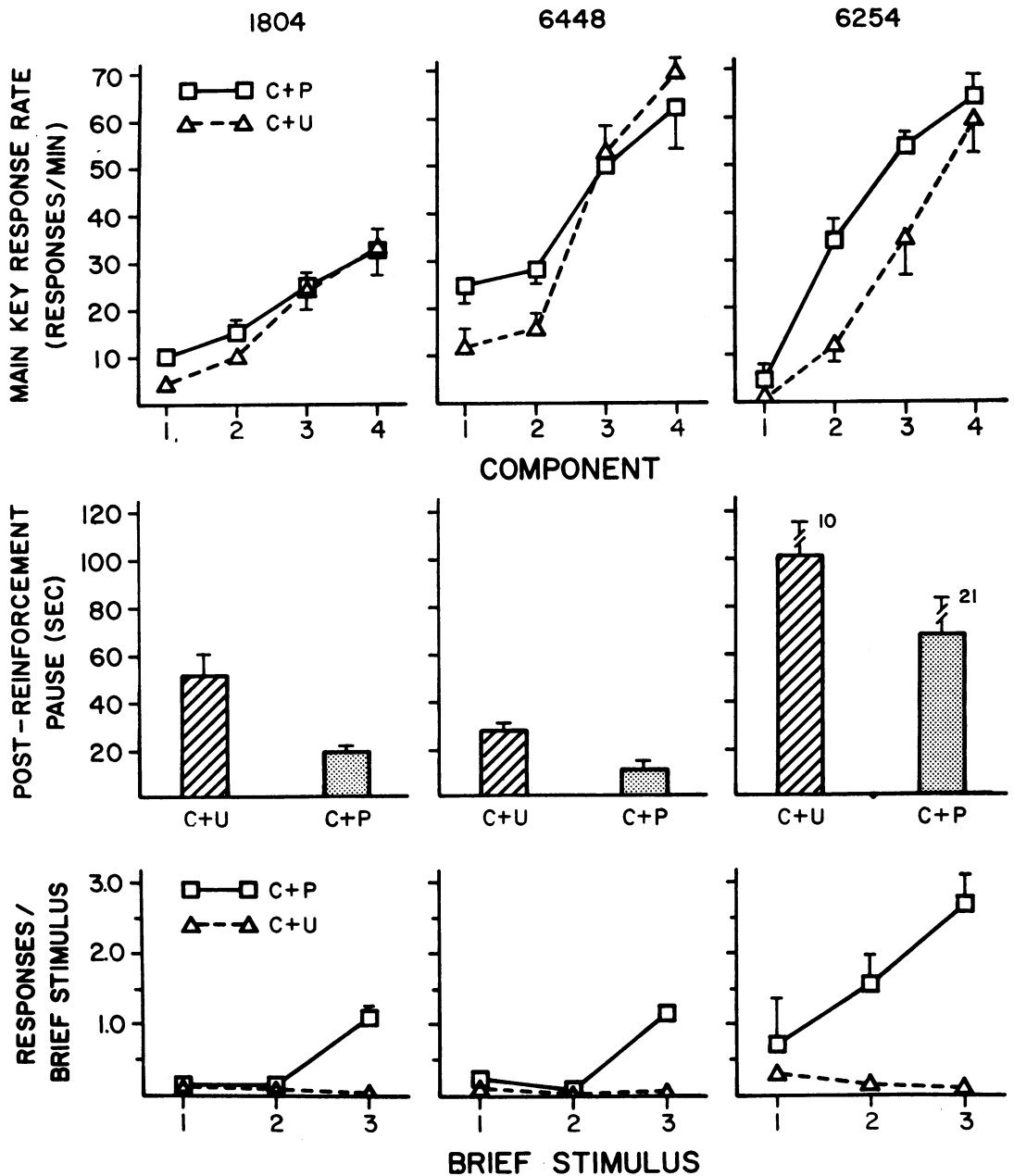


Fig. 7. Main-key response rates, postreinforcement pauses, and brief-stimulus key responses per brief-stimulus presentation for the chain + unpaired (C+U) versus chain + paired (C+P) condition. Data represent averages over five sessions; vertical bars denote one standard deviation (bars are omitted if they end within a data symbol).

shows the postreinforcement pause data from Condition 2. Again, there is a good deal of similarity to the results from the previous condition. The chain + paired schedule engendered much shorter pauses, on the average, than the chain + unpaired schedule. This difference was significant for Pigeons 1804 and

6448, but the large variability in the data from Pigeon 6254 precluded it reaching statistical significance.

The discrimination data (third row) reflect a sharp discrimination between the paired and unpaired brief stimuli on the third presentation, as well as a discrimination between the

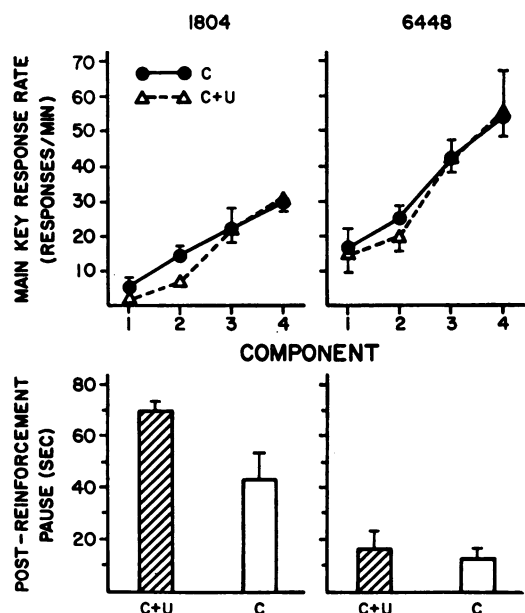


Fig. 8. Main-key response rates and postreinforcement pauses for the chain + unpaired (C+U) versus chain (C) condition. Data represent averages over five sessions; vertical bars denote one standard deviation (bars are omitted if they end within a data symbol).

first two paired brief stimuli and subsequent ones.

Figure 8 shows the results from Condition 3 for Pigeons 1804 and 6448. A slight rate enhancement was evidenced in the first two components of the chain schedule for Pigeon 1804, which was also reflected in the pause data; Pigeon 6448, however, showed a difference in performance only in the second component. Pigeon 6254 showed a decline in responding over the first several sessions, and by the tenth session it was obtaining reinforcement at an extremely low rate, with pauses as long as 50 min occurring between responses. It was then taken off the schedule and, hence, data were not obtained for this condition. Instead, this subject was returned to Condition 2 for several sessions until its responding recovered.

DISCUSSION

Converting the main-key schedule to a chain schedule was generally quite successful in producing a discrimination between the earlier and later brief stimuli, thus replicating the same finding by Squires *et al.* (1975). At the same time, however, the early response-

rate enhancement and shorter postreinforcement pause persisted in the schedule with the paired brief stimuli (*cf.* Malagodi *et al.*, 1973). This suggests that the conditioned reinforcement effect was relatively independent of the discriminative effects of the brief stimulus, arguing against the temporal control interpretation discussed previously. While one might not have expected a perfect correspondence between responding on the main key and brief-stimulus key, what was found seems to be a total lack of such a correspondence. In fact, the enhancement of main-key response rates for the paired schedule became clearer in the first two components during Condition 1 of Experiment II (upper panels, Figure 6) than it had been in Condition 1 of Experiment I (upper panels, Figure 2) for all subjects. Specifically, whereas the response-rate enhancement for the paired schedule was significant for two of three birds in the first component, but for none in the second component in Experiment I, Condition 1, this enhancement was significant in both components for each bird in Experiment II, Condition 1. This was true despite a concomitant drop in responding on the brief-stimulus key during early presentations (compare lower panels, Figure 6, with those in Figure 2). Similarly, for Pigeon 1804, the response-rate difference in the second component became significant during Condition 2 of Experiment II (upper-left panel, Figure 7), where previously, in Conditions 2 and 3 of Experiment I (upper-left panels, Figures 3 and 4) it was not. Comparisons for the other two subjects were difficult to make, in that relative and absolute comparisons between response rates yielded different conclusions. In any case, a substantial lack of agreement between the two measures, main-key responding and brief-stimulus key responding, was observed.

Pecks directed at the brief stimulus might well have been elicited, or Pavlovian, responses, stemming from the correlation between that stimulus and an increase in the probability of reinforcement (Gamzu and Schwartz, 1973). Since the establishment of conditioned reinforcement may also be a Pavlovian process, other demonstrations of divergences between classically conditioned response systems are relevant to the above results. For example, Yehle (1968) showed that heart rate and nictitating membrane responses

conditioned to the same stimuli not only conditioned at different rates, but also that a conditional discrimination could be established with one response and not with the other. Numerous studies illustrating a lack of correspondence between response systems conditioned to the same stimuli can be cited (*e.g.*, Black and de Toledo, 1972; Schneiderman, 1972). What was perhaps surprising in the present experiment, though, was that a divergence in responding occurred between responses essentially of the same form, *i.e.*, key pecks. It is possible that a closer examination would show differences in response topography distinguishing main-key responses from those directed at the brief stimulus, analogous to the difference between short- and long-duration pecks reported by Schwartz and Williams (1972). Further research is needed to clarify the conditions under which such dissociation between reinforcement and discriminative control can be obtained.

The present results are also consistent with findings in the operant literature of conditioned reinforcement in the signalled absence of primary reinforcement (Thomas, 1969) and the maintenance of responding by a food-paired stimulus for many sessions after removal of primary reinforcement (Zimmerman and Hanford, 1967).

Although the results favor a conditioned reinforcement interpretation, an analysis in terms of temporal control is not entirely ruled out, as a brief stimulus may disrupt temporal control regardless of whether the subject responds to it; responses to the brief stimulus may be inhibited when the brief stimulus appears in the presence of the first stimulus of the chain (which is reliably correlated with nonreinforcement).

These hypotheses were evaluated further in Experiment III by manipulating the dependency between responding and production of brief stimuli in the early schedule components.

EXPERIMENT III

Experiment III systematically manipulated the dependencies between responding and the various stimulus changes that occurred in the multiple schedule consisting of the chain + unpaired and chain + paired schedules employed in the previous experiment. In particular, the consequences of main-key responding

in Experiment II were threefold: production of a brief stimulus if the opportunity had been arranged by the component FI or VI schedule, advancement to the next component of the schedule, and the change in main-key color at the end of the second component.

An interpretation of second-order schedule performance in terms of conditioned reinforcement would require that the production of a paired brief stimulus be important in maintaining behavior, as well as generating the rate enhancements seen in the paired brief-stimulus schedules. Thus, removing this consequence of responding should result in a decline in response rates, with the difference between performance under paired and unpaired brief-stimulus schedules diminishing. On the other hand, if the main effects of brief stimuli are discriminative in nature, behavior in a response-independent schedule should be similar to that in a contingent one.

Various studies have supported each of these predictions, depending on the procedures involved. For example, Marr and Zeiler (1974) and Stubbs (1971) found similar effects of brief stimuli on response patterning, regardless of whether they were dependent on responding. Other studies have found the opposite, that rates and patterns of responding are in general influenced by the schedule according to which brief stimuli are presented (Thomas, 1969; Zimmerman, 1969). To determine the effect of manipulating this scheduling feature while concurrently measuring the discriminative control exerted by the brief stimuli, we performed the following experiment.

METHOD

Subjects and Apparatus

The same subjects and apparatus were used as in Experiments I and II.

Procedure

The basic paradigm was the same as in Condition 2 of Experiment II, in which chain schedules with paired and unpaired brief stimuli were combined in a multiple schedule. The experiment consisted of four phases in which the main-key response contingencies were systematically manipulated.

In the first phase of Experiment III, all the dependencies were removed during the first

two components, *i.e.*, the occurrence of the first two brief stimuli, advancement through the first two components, and the change in main-key color all proceeded irrespective of responding. This condition remained in effect for only a few (under 10) sessions in order to verify that responding would be sensitive to schedule manipulations and to lower the response rates sufficiently to allow the transition to Phase 2.

In the second phase, to which only Pigeons 1804 and 6254 were exposed, a 3-sec mandatory delay was interposed between any response on either key and the occurrence of a brief stimulus. Each response during the first two components reset a timer, so the necessary conditions for the occurrence of a brief stimulus (as well as the main-key color changes) were that it was arranged by the component schedule, and that the 3-sec timer had timed out. The purpose of the 3-sec delay was to prevent the maintenance of superstitious responding by accidental correlations between a response and the occurrence of a stimulus change. In this condition, however, as well as the subsequent ones, one of the dependencies was reintroduced: that between responding and advancement through the initial components, so that food could not be obtained without at least two responses having been emitted (at times when the VI timer had arranged to be effective) in the first two components. No exteroceptive stimulus change accompanied the advancement to the next component, so to the extent responding did occur it was due to delayed consequences. Pigeon 1804 was exposed to 17 sessions and Pigeon 6254 was exposed to 14 sessions under this schedule.

The third phase, which was in effect for all subjects, consisted in reintroducing the dependency between responding and the change in main-key color at the end of the second component. Now, the only noncontingent stimulus change was the presentation of the first two brief stimuli, with a 3-sec mandatory delay still in effect. Subjects were exposed to Phase 3 for the following numbers of sessions: Pigeon 1804, 21 sessions; Pigeon 6448, 34 sessions; Pigeon 6254, 36 sessions.

The final phase was a return to the condition in which every stimulus change was response dependent, and the schedule became identical to that employed in Condition 2 of

Experiment II. Pigeons 6448 and 6254 received 31 sessions in this condition; Pigeon 1804 received 38 sessions.

In none of the above conditions did the dependencies in the third and fourth components change from what they were in Experiment II. In each condition, the component schedules, the colors of the main key in both portions of the chain schedules, and the brief-stimulus colors were identical to those in Condition 2 of Experiment II for each pigeon.

RESULTS

Results were subjected to the same statistical analysis as in the preceding experiments. Again, all differences noted below were significant beyond the $p = 0.05$ level. The first dependency manipulation of Phase 1 resulted in an immediate decline in responding during the first two components for all subjects, although they were not exposed to the condition long enough to obtain stable response rates. By the fifth session of this condition, first component response rates in the unpaired brief-stimulus schedule had dropped to zero responses per minute for Pigeon 1804, 13 responses per minute for Pigeon 6448, and zero responses per minute for Pigeon 6254. First component rates in the paired brief-stimulus schedule were four responses per minute for Pigeon 1804, 17 responses per minute for Pigeon 6448, and five responses per minute for Pigeon 6254. Thus, low rates of responding were observed shortly after the removal of all dependencies. This allowed an easy transition to Phase 2, in that responding was low enough that 3-sec interresponse times were not uncommon.

The upper panels in Figure 9 present the response-rate results from Phase 2. The main-key response rates are plotted as a function of components. First, it can be seen that for Pigeon 1804 there is no appreciable difference between responding under paired and unpaired brief-stimulus schedules in any component, although there was a slight, significant enhancement in the first component of the paired brief-stimulus schedule. Also, the absolute rate of responding was quite low in comparison to the level in Experiment II (*cf.* upper-left panel, Figure 7). Responding in the first component of the paired brief-stimulus schedule was reduced by 90%, that in the second component by 70%. For Pigeon 6254,

there remained a rate enhancement in all components of the paired brief-stimulus schedule. The reductions in responding in the paired brief-stimulus schedule from that in Experiment II (upper-right panel, Figure 7) were approximately 75% in the first component and 30% in the second component. Main-key responding in the components with response dependencies intact was virtually unaffected by the dependency manipulations in the earlier components, including the rate enhancement that Pigeon 6254 showed in the later components of the paired brief-stimulus schedule.

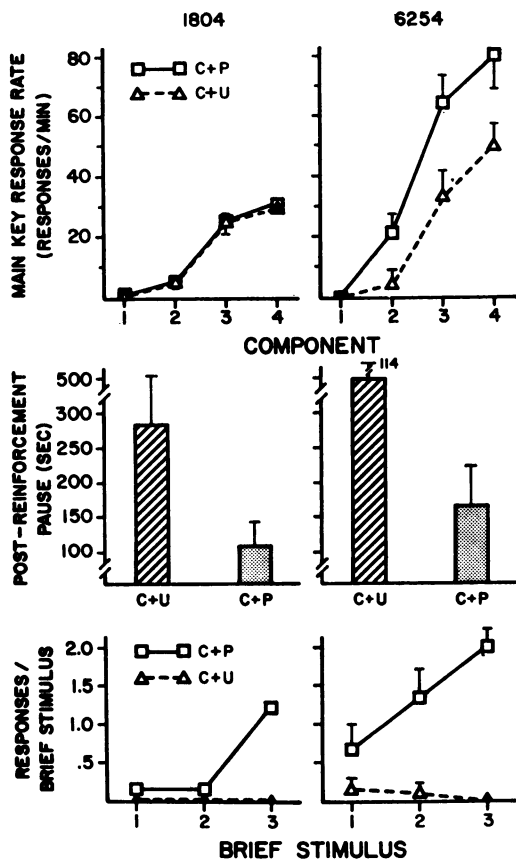


Fig. 9. Main-key response rates, postreinforcement pauses, and brief-stimulus key responses per brief-stimulus presentation for the Phase 2 chain + unpaired (C+U) versus chain + paired (C+P) comparison, with all dependencies removed in the first two components, except the dependency between responding and advancement through the components (unaccompanied by stimulus changes). Data represent averages over five sessions; vertical bars denote one standard deviation (bars are omitted if they end within a data symbol). All unbroken error bars are drawn using the same scale as that in the unbroken portion of the ordinate.

The postreinforcement pause data are displayed in the middle panels of Figure 9. Pausing increased dramatically over the contingent chain + unpaired versus chain + paired comparison of Experiment II and, as a consequence, reinforcement was not obtained with the frequency scheduled. There was also a difference shown in the average postreinforcement pause between the paired and unpaired brief-stimulus schedules, with shorter pauses occurring in the former.

The bottom graphs in Figure 9 show the discrimination data, *i.e.*, the average number of brief-stimulus key responses during each of the first three brief-stimulus periods. Pigeon 1804 emitted few responses to the first two brief stimuli and responded to every brief stimulus occurring during the second link of the chain signified by the main-key color. Pigeon 6254 did not discriminate well, as evidenced by a substantial number of responses made to the early brief stimuli. There was a clear gradient, however, of responses emitted to successive brief stimuli.

The Phase 3 response-rate data appear in Figure 10 (top row). Although the contingency between main-key responding and the change in main-key color was reinstituted, there was little change in response rates for Pigeons 1804 and 6254. The difference in response rates between the paired and unpaired brief-stimulus schedules was significant for Pigeon 6254 in the second, third, and fourth components. There was no difference for any component in the case of Pigeon 1804. Pigeon 6448, also exposed to this condition, showed no response-rate differences between the schedules in the first two components, but did show a rate enhancement during the later components in which brief stimuli were contingent on responding.

The postreinforcement pause data (middle row) show that pauses were considerably shorter than in the previous condition for Pigeons 1804 and 6254. The difference in the length of pause between paired and unpaired brief-stimulus schedules remained only for Pigeon 1804. Pigeon 6448, which was not exposed to the previous condition, showed the same average postreinforcement pause in the chain + unpaired as the chain + paired schedule.

The lower row of graphs in Figure 10 presents the discrimination data for this condi-

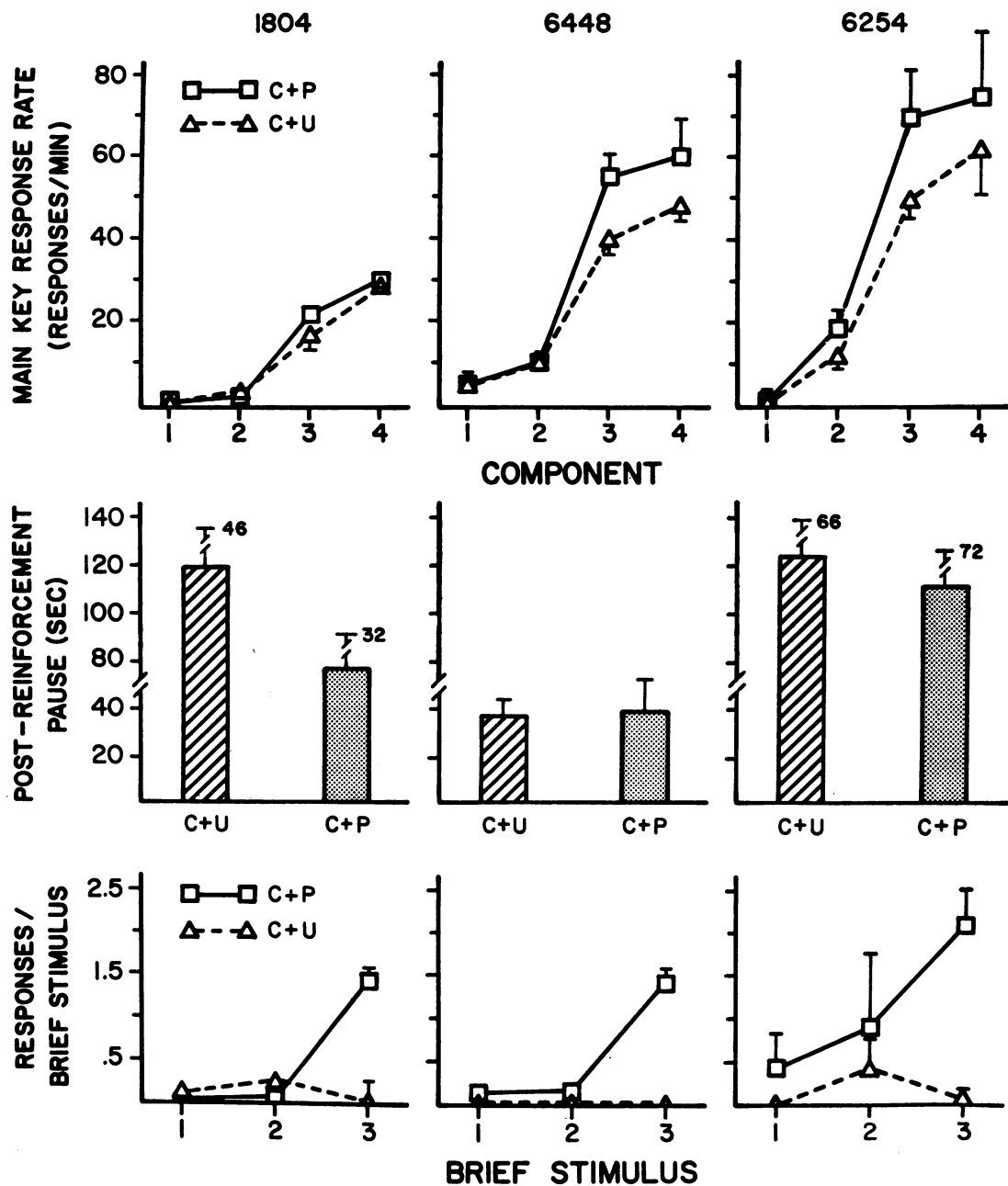


Fig. 10. Main-key response rates, postreinforcement pauses, and brief-stimulus key responses per brief-stimulus presentation for the Phase 3 chain + unpaired (C+U) versus chain + paired (C+P) comparison. The dependency between responding and the change in main-key color at the end of the second component had been restored; only the brief stimuli were noncontingent. Data represent averages over five sessions; vertical bars denote one standard deviation (bars are omitted if they end within a data symbol). All unbroken error bars are drawn using the same scale as that in the unbroken portion of the ordinate.

tion. As before, there were not many responses made to the first two brief stimuli by Pigeons 1804 and 6448, whereas Pigeon 6254 showed the same kind of response gradient as was

seen in the previous condition. The third brief stimulus, occurring as it did during the second link of the chain, elicited many responses.

The data from Phase 4, *i.e.*, the return of the brief-stimulus dependency to the chain + unpaired and chain + paired schedules, are presented in Figure 11. The upper set of graphs shows the main-key response rates. Response rates recovered almost completely to their former levels in the case of Pigeon 6448, with response rates in the chain + paired schedule significantly above those in the chain + unpaired schedule in the first, second, and fourth components. For Pigeon 1804, only the differences in the first and second components were significant; for Pigeon 6254, those in the third and fourth components were significant. The absolute level of responding showed a partial recovery in the case of Pigeon 1804. Pigeon 6254 showed no such recovery and showed no difference in the second component response rates under the two schedules, which it had shown in the previous response-independent condition (upper-right panel, Figure 10). However, a significant response-rate difference appeared in both the first and second components for the two subjects, Pigeons 1804 and 6448, which previously (upper panels, Figure 10) had not produced a difference.

The postreinforcement pauses (second row) demonstrate a full recovery for Pigeon 6448 (see center panel, Figure 7). Pigeon 1804, however, still showed somewhat longer pauses than in Condition 2 of Experiment II (middle row, left panel of Figure 7). Pigeon 6254 continued to display much longer pauses than in Experiment II (middle row, right panel of Figure 7). For Pigeons 1804 and 6448, the pause in the chain + paired schedule was consistently shorter than in the chain + unpaired schedule, whereas there was no significant difference for Pigeon 6254.

The discrimination data are presented in the lower panels of Figure 11. Each pigeon showed a similar pattern of responding to that in Experiment II (bottom panels, Figures 6 and 7).

DISCUSSION

The above results suggest that the dependency between main-key responding and production of the paired brief stimuli was responsible for a major portion of responding in the first two components. This is shown by the decline in response rates during these components following removal of the contingencies, by the continued depression when all conse-

quences except the brief stimuli were reinstated, and by the recovery in absolute rate of responding (for two of three subjects) when the brief-stimulus dependency was finally restored.

The rate enhancement in the chain + paired relative to the chain + unpaired schedule diminished or disappeared as well in the conditions with noncontingent brief stimuli. The results of Pigeon 6448 (upper-middle panels, Figure 10), showing a rate enhancement in the third and fourth components (in which there was a brief-stimulus dependency) and no differential responding in the first two components (having no such dependency) provide the clearest results for the effects of the brief-stimulus dependency. The results from Pigeon 6254 (upper-right panels, Figures 9 and 10), while also implicating this relation, suggest that some of the observed rate enhancement was independent of this dependency. That Pigeons 1804 and 6254 did not recover fully their baseline performance when the dependency was returned may have been due to the additional prolonged exposure to Phase 2. These two subjects also continued to show somewhat shorter pausing in the chain + paired schedule than in the chain + unpaired schedule throughout the contingency manipulations, although the absolute length of the pause in both schedules increased greatly over Condition 2 of Experiment II, in which stimulus changes were contingent on responding.

Taken together, these data support the following conclusion: less responding is maintained by response-independent brief-stimulus presentations than dependent presentations, and to the extent that paired brief-stimulus schedules show a rate enhancement relative to comparable unpaired brief-stimulus schedules, the effect is largely due to the brief-stimulus dependency. This conclusion is consistent with the fact that most studies that have found little sensitivity to dependency manipulations have also not found a rate enhancement in paired brief-stimulus schedules (*e.g.*, Marr and Zeiler, 1974; Stubbs, 1971). In contrast, two studies in which behavior was sensitive to manipulations of the brief-stimulus dependency (Thomas, 1969; Zimmerman, 1969) also showed differential rate effects of paired and unpaired brief stimuli.

The possibility exists that the 3-sec delay between a response and some or all stimulus changes, imposed during Phases 2 and 3, may

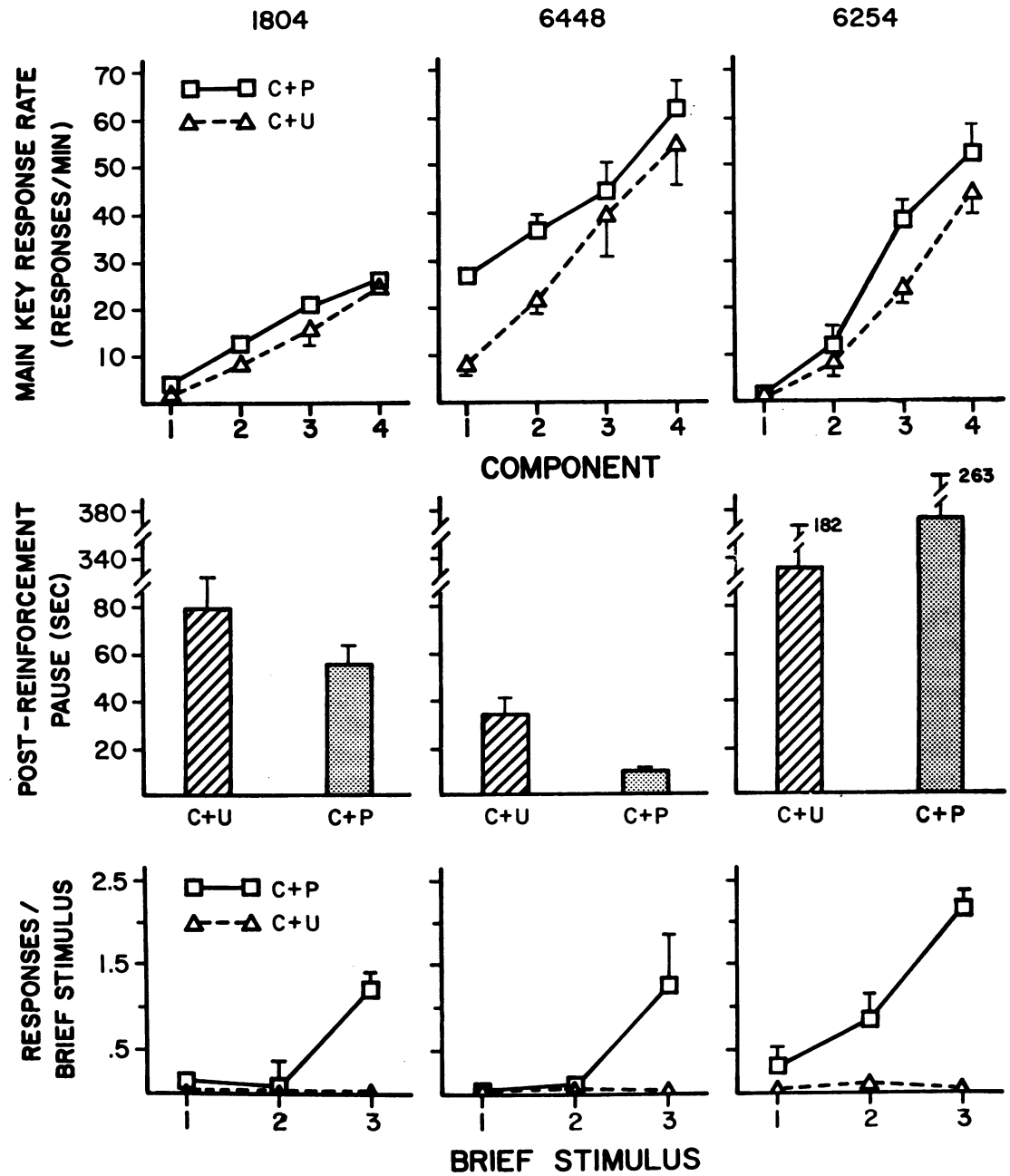


Fig. 11. Main-key response rates, postreinforcement pauses, and brief-stimulus key responses per brief-stimulus presentation for the Phase 4 chain + unpaired (C+U) versus chain + paired (C+P) comparison, with all dependencies restored. Data represent averages over five sessions. Vertical bars denote one standard deviation (bars are omitted if they end within a data symbol). All unbroken error bars are drawn using the same scale as that in the unbroken portion of the ordinate.

have had an independent effect on behavior, which masked any evidence of conditioned reinforcement. This seems unlikely, however, for two reasons. First, a decline in response rates was observed in Phase 1, before the delay

was instituted, suggesting that this effect was not dependent on the delay contingency. Second, the only obvious result of the delay contingency, besides preventing adventitious reinforcement of responding, was to postpone the

ultimate delivery of food until the requirement was satisfied in the first two components. While an increase in the interreinforcement interval might have itself contributed to longer pauses (Nevin, 1973), Shull (1970) showed that pigeons are relatively insensitive to operant contingencies involving such delayed effects of responding. He presented pigeons with response-initiated FI schedules, *i.e.*, tandem FR 1 FI X, in which the optimal strategy to obtain food quickly was to respond immediately after a food presentation. Instead, Shull found that the birds paused about as long as the nominal FI value, *e.g.*, 1 min for a tandem FI 1-min FI 1-min schedule, even though it resulted in doubling the time to food. Thus, it becomes somewhat implausible to suppose that the delay to food, rather than the removal of the brief-stimulus dependency, was solely responsible for the decline in responding observed in the present experiment, and further that this differentially affected behavior in the chain + paired schedule so as to eliminate or lessen performance differences between the paired and unpaired brief-stimulus schedules.

No systematic trend was observed within subjects in brief-stimulus responding during the various conditions of the present experiment, *i.e.*, the contingency effects were independent of any simultaneous changes in the discriminative control over responding exerted by the brief stimuli. The only evidence for such a trend between subjects was the fact that the subject showing the least sensitivity to the manipulations, Pigeon 6254, also evidenced the poorest discrimination between successive brief stimuli. The component schedule was an FI 1-min for this subject as well, and that may have been partly responsible for both the poor discrimination and the lessened influence of dependency manipulations.

It may be possible to amend the statement of the temporal control interpretation to include the results of the present experiment, if it is assumed that contingent brief stimuli are more similar to primary reinforcement than noncontingent ones, and hence interfere more with temporal control. It might appear difficult to distinguish such a hypothesis from that of conditioned reinforcement, and the choice of terminology would seem to depend on either simplicity, or on which is more consistent with a more general theoretical framework.

In the following discussion, though, the conditioned reinforcement terminology is employed, as it seems most consistent with the results obtained. In one sense, the concepts of conditioned reinforcement and temporal control are quite compatible, however, because to the extent that paired brief stimuli act as reinforcers, responding will come under the control of the component schedule, rather than the schedule of food presentations; hence, temporal control arising from the periodicity of primary reinforcement will necessarily become less apparent. The following experiment attempted to probe further the factors affecting the conditioned reinforcement strength of brief stimuli paired with food.

EXPERIMENT IV

In Experiments II and III, the chain schedule on the main key included only the first two components of the second-order schedules involved. Brief-stimulus key responding remained high to the third and final brief stimuli in the chain + paired schedule. The following experiment extended the chain schedule on the main key to include the third schedule component as well as the first two, in order to determine what effect this might have on responding in the earlier components, especially the rate enhancement often seen in the chain + paired schedule.

The pairing hypothesis of conditioned reinforcement would predict that responding in the first link of the chain + paired schedule be maintained at a higher level than in the chain + unpaired schedule, just as in Experiment II. Studies of observing responses (*e.g.*, Auge, 1974) have shown, however, that the ability of a stimulus to maintain observing behavior depends not on its being paired with food, *per se*, but by the degree of association with primary reinforcement relative to that signalled by other discriminative stimuli in the situation. Accounts in terms of the relative density of primary reinforcement or relative reduction in time to reinforcement have generally been more successful in predicting these results than either information theory or the pairing hypothesis of conditioned reinforcement (see Fantino, 1977, for a review).

If the context in which a food-paired stimulus appears is indeed important in determining whether it will acquire conditioned rein-

forcing strength, then varying the relative durations of the chain stimuli in a second-order schedule might affect the conditioned reinforcing properties of the paired brief stimuli. The shorter the terminal-link chain stimulus, the more effective a conditioned reinforcer it should be. The paired brief stimulus might become relatively weak by comparison. In particular, as the initial link of the chain schedule is extended to include the third component of the second-order schedule, then compared with the chain schedules in Experiment II, the onset of the terminal-link stimulus is approximately twice as close in time to the delivery of primary reinforcement and is correlated with a greater reduction in time to reinforcement ($\frac{3}{4}$ instead of $\frac{1}{2}$; see Fantino, 1977). It might be expected, therefore, that the effective conditioned reinforcing strength of the paired brief stimuli would be less than in the preceding experiment, due to the increased association with primary reinforcement of the context in which the brief stimuli appear, *i.e.*, the terminal-link stimulus. If so, the rate enhancement in the paired brief-stimulus schedule should decline.

METHOD

Subjects and Apparatus

The three subjects from the previous experiments, plus one additional male White Carneaux pigeon (9117), were employed in Experiment IV.

Procedure

The procedure was basically similar to that of Condition 2 of Experiment II: a multiple schedule in which one component was a chain schedule with paired brief stimuli presented at the end of each of four components, and the other component was a chain schedule with unpaired brief stimuli occurring at the end of all but the last component. The only difference in the present procedure was that the main-key color signalling the chain schedule did not change until production of the third (instead of the second) brief stimulus in the paired and unpaired brief-stimulus schedules. The key colors on both the main and brief-stimulus keys were the same as in the second condition of Experiment II for Pigeons 1804, 6448, and 6254.

Pigeon 9117 was first exposed to simple second-order schedules [FR 4 (VI 1-min)] of paired and unpaired brief stimuli as well as a tandem schedule; the dependencies in these schedules were identical to those in the corresponding components of the multiple schedules employed in Experiment I. The sequence of exposure to the conditions was: paired (19 sessions), unpaired (26 sessions), tandem (14 sessions), paired (14 sessions). The paired brief-stimulus color was white and the unpaired brief stimulus was blue throughout the experiment. The main-key color was red in the first exposure to the paired brief-stimulus schedule, yellow in the unpaired brief-stimulus schedule, and green in the tandem schedule and also in the second presentation of the paired brief-stimulus schedule. When this pigeon was placed on the same multiple schedule as the other three pigeons, the sequence of main-key colors was red and yellow in the chain + unpaired schedule and orange and green in the chain + paired schedule.

The numbers of sessions each pigeon spent on the multiple-schedule condition were as follows: Pigeon 1804, 29 sessions; Pigeon 6448, 33 sessions; Pigeon 6254, 31 sessions; Pigeon 9117, 27 sessions.

RESULTS

The same statistical criteria were used to evaluate results from the present experiment as were employed in Experiments I to III. Again, all differences noted below were significant beyond the $p = 0.05$ level.

The data for Pigeon 9117 are presented in Table 2, and the simple schedule results were entirely comparable to those from the other subjects in Experiment I. In particular: (1) response rates were higher in initial components of the paired brief-stimulus schedule, in both initial and final determinations, than in the tandem or unpaired brief-stimulus schedules; (2) response rates in the terminal component of the tandem schedule were somewhat higher than in the paired brief-stimulus schedule; (3) postreinforcement pauses were shortest in the paired brief-stimulus schedules; (4) responding occurred to a large proportion of the paired brief stimuli, with somewhat more responding occurring the later the brief stimulus; (5) responses rarely occurred to unpaired brief stimuli. The multiple schedule results show no difference in performance between

Table 2

Results from Pigeon 9117, Exposed to Both Simple and Multiple Schedules (Experiment IV)

Condition	Main-Key Response Rates (responses/min)				Post-Reinforcement Pause (sec)	Brief-Stimulus Key Responses per Brief Stimulus		
	Component					Brief Stimulus		
	1	2	3	4		1	2	3
Paired	16 ± 3.6	29 ± 2.9	36 ± 2.3	41 ± 1.3	26 ± 3.5	0.7 ± 0.18	1.1 ± 0.15	1.2 ± 0.06
Unpaired	0.9 ± 0.2	14 ± 3.8	32 ± 2.9	46 ± 5.2	186 ± 37.4	0	0	0
Tandem	1.1 ± 1.4	15 ± 5.9	40 ± 6.7	52 ± 5.3	158 ± 58.2	0	0	0
Paired	10 ± 2.2	28 ± 4	38 ± 1.9	47 ± 1.5	47 ± 7	0.6 ± 0.09	1.0 ± 0.15	1.2 ± 0.15
Chain+Unpaired	6.9 ± 5.3	25 ± 5.6	30 ± 3.4	50 ± 2.4	71 ± 22.3	0	0	0
vs. Chain+Paired	6.1 ± 3.5	26 ± 5.8	33 ± 3.6	49 ± 3.0	47 ± 9.8	0	0.04 ± 0.05	0.02 ± 0.04

the chain + paired and chain + unpaired schedules, except for a slightly shorter pause in the chain + paired schedule.

The main-key response-rate results from Pigeons 1804, 6448, and 6254 in the multiple chain + unpaired and chain + paired schedule are plotted in the upper row of graphs in Figure 12. There were no significant differences in any component for Pigeons 1804 and 6254. Pigeon 6448 showed an enhancement in the first and fourth components, the other differences falling short of significance.

Postreinforcement pause results are depicted in the middle panels of Figure 12. No difference in pause length was evidenced by any subject.

Finally, the discrimination data are presented in the lower graphs in Figure 12. The average number of responses to each of the brief stimuli is shown for the chain + unpaired and chain + paired schedules. The main-key color was again effective in suppressing most responses to the first three brief stimuli, with the possible exception of Pigeon 6254, although it too emitted far fewer responses to the third paired brief stimulus than previously.

DISCUSSION

Comparing the results from the present experiment with those from Phase 4 of Experiment III (upper panels, Figure 11), it can be concluded that extending the chain schedule on the main key had a clear effect on responding in early components. The elevation of response rates in the first component of the chain + paired over that in the chain + unpaired schedule diminished or disappeared for Pigeons 1804 and 6448. In addition, the difference in third-component response rates that had been exhibited by Pigeon 6254 was no

longer evidenced. Pigeon 9117 showed no difference in first-component response rate between paired and unpaired brief-stimulus schedules, whereas previously, when exposed to the simple schedules, it had shown a substantial rate enhancement in the paired brief-stimulus schedule.

Thus, it appears that the context in which the paired brief stimuli occur, as well as the pairing operation, affect the degree to which they act as conditioned reinforcers. A diminution in reinforcing effectiveness seems to have resulted from an increase in the strength of another conditioned reinforcer in the situation, the terminal-link stimulus. These results are reminiscent of Egger and Miller's (1962) finding that the conditioned reinforcing effectiveness of a stimulus depends on the number of times it occurred without food, as well as the presence of other stimuli paired with food.

Such a relative view of conditioned reinforcement may also account for some of the failures to demonstrate the conditioned reinforcing properties of the discriminative stimuli comprising a chain schedule. Byrd (1971), for example, presented pigeons with a seven-component chain schedule in which the terminal-link color appeared also in the earlier, odd-numbered, components. Unique colors were associated with the other components. In one phase of the experiment, he compared responding under this schedule to that under a similar schedule in which only the stimuli in the first, third, and fifth components were the same color and the terminal-link stimulus was a different color. If being paired with food endowed the terminal-link color with conditioned reinforcing properties, then responding in the second and fourth components should have been elevated in the former condition

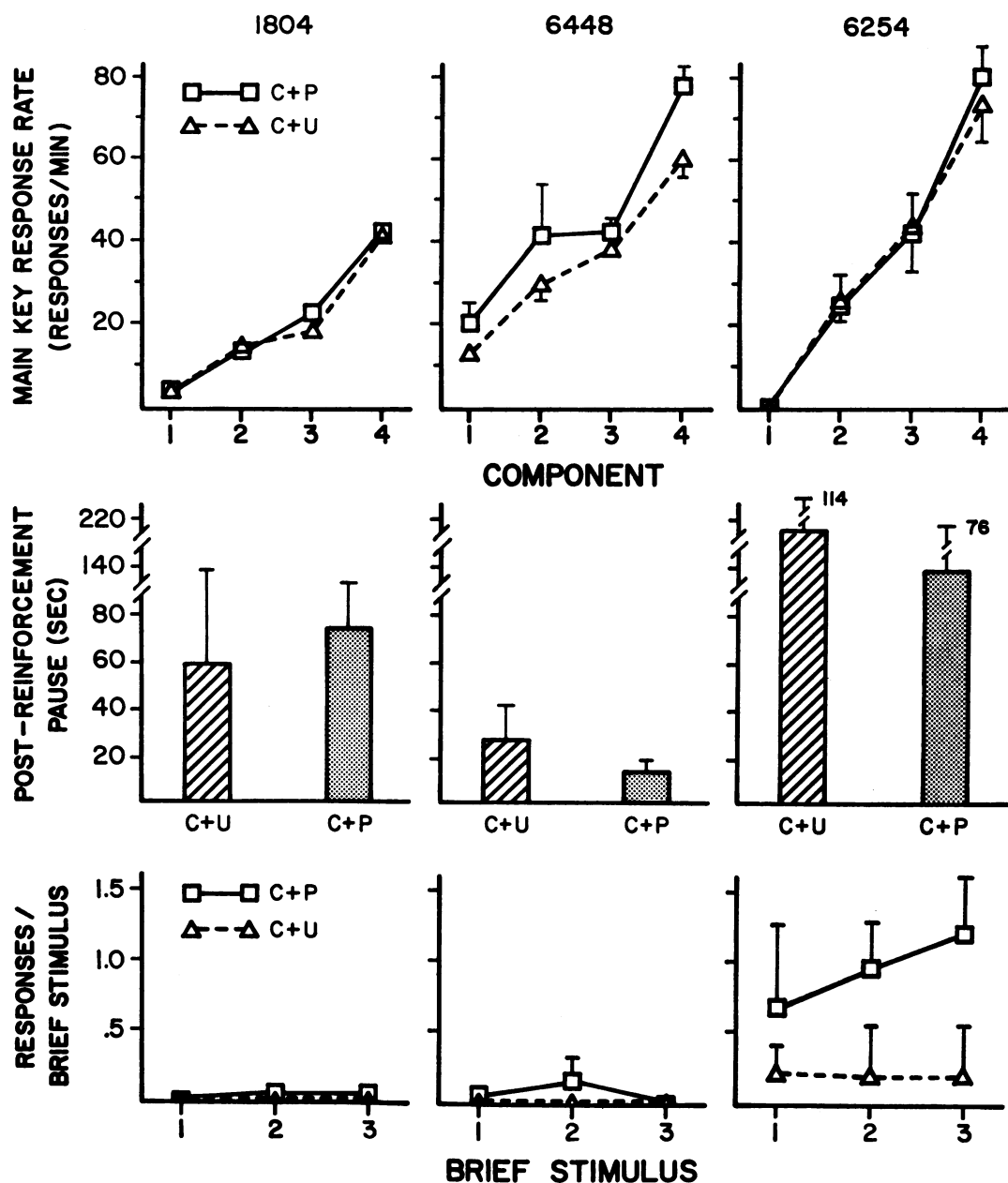


Fig. 12. Main-key response rates, postreinforcement pauses, and brief-stimulus key responses per brief-stimulus presentation for the chain + unpaired (C+U) versus chain + paired (C+P) comparison of Experiment IV, in which the first link of the chain schedule included the first three components. Data represent averages over five sessions; vertical bars denote one standard deviation (bars are omitted if they end within a data symbol). All unbroken error bars are drawn using the same scale as that in the unbroken portion of the ordinate.

relative to the latter. Instead, Byrd found no difference. His data did show, however, that there was a substantial rise in response rates during the penultimate link of the chain schedule in the second condition (*i.e.*, the one with a unique terminal-link stimulus). In light of

the present arguments, these results may be interpreted as having shown an increase in the conditioned reinforcing strength of the terminal-link stimulus when it was unique. That is, in the first condition, the extensive presentation of the terminal-link color through-

out the schedule may have weakened its reinforcing strength relative to that when it appeared only in the terminal link. The present results suggest that similar context-dependent effects may be extended to the stimuli occurring in second-order schedules of brief-stimulus presentations.

The temporal control hypothesis may account for some of the results of the present experiment. In terms of that view, the occurrence of food was most reliably correlated with the terminal-link stimulus and the absence of food was reliably signalled by the initial-link stimulus. Hence, temporal confusion should have been minimized and rate enhancements in the chain + paired schedule would have been expected to diminish. It remains unanswered, however, why Pigeon 6254 still responded to most paired brief stimuli and yet failed to show a rate enhancement (especially in the third component).

GENERAL DISCUSSION

The results from the preceding experiments display a rather complex interaction between the effects of stimuli presented in second-order schedules. Paired brief stimuli seem to have a clear effect on main-key responding, which often appears as an enhancement of early responding over that found in tandem or unpaired brief-stimulus schedules. The stimuli on the main key, in turn, control brief-stimulus responding, as shown by the results from Experiment II, as well as by the chain schedule condition in Squires *et al.* (1975). The relationship between the color of one key and responding on the other key is thus reciprocal. Responding to each key is to some extent independent of responding to the other, however, as the following results in the present experiments have shown: (1) manipulations that radically altered brief-stimulus responding sometimes had little effect on main-key responding, as the introduction of two main-key colors in Experiment II; (2) main-key responding could change considerably without a corresponding change in brief-stimulus key responding, as was demonstrated in Experiment III; and (3) there was an absence of a negative correlation between the degree of brief-stimulus discrimination and the amount of rate enhancement shown in the paired brief-stimulus schedules. For example, in Phase 4 of

Experiment III (Figure 11), Pigeon 6448 evidenced a clearer discrimination between paired brief stimuli than Pigeon 6254, yet showed rate enhancement in the first component of the paired brief-stimulus schedule; Pigeon 6254 did not. Other examples were pointed out in the discussion of Experiment II.

Therefore, we can conclude that at the present level of analysis, the functions of paired brief stimuli in second-order schedules cannot be reduced solely to either a discriminative or reinforcing effect. Further, the preceding experiments illustrate how the relative contribution of each effect can be manipulated. For example, in Experiment I, both reinforcing and discriminative functions of the paired brief stimuli were apparent. In Experiment II, however, the reinforcing function of the early brief stimuli remained while their discriminative control was minimized. Experiments III and IV showed that the discriminative function could persist in some cases without a corresponding reinforcing effect. Thus, the occurrence of rate enhancement in paired *versus* equivalent unpaired brief-stimulus schedules seems to be dependent on several factors, including the salience of the brief stimuli (both paired and unpaired), the context in which the paired stimuli occur (such as the chain stimuli in Experiments II to IV of the present study), and the contingent relations between responding and brief-stimulus presentations (implicated by the data from Experiment III). It is likely that this multiple determination of responding in brief-stimulus schedules is responsible for the inconsistency of much of the prior literature in this area, a conclusion also reached by Gollub (1977) in his review.

The present results replicate the Squires *et al.* (1975) finding that pigeons do not discriminate between components of paired brief-stimulus schedules when the components are FI schedules and extend this finding to VI schedules. As in the previous study, pigeons continued to peck the paired brief stimuli at every opportunity unless additional color cues were provided. Unlike Squires *et al.* however, the present study, utilizing a multiple schedule procedure (after de Lorge, 1971) showed that paired brief-stimulus schedules tend to control higher rates of responding than unpaired brief-stimulus schedules. The most straightforward conclusion is that this rate enhancement arises primarily from the condi-

tioned reinforcing value of the paired brief stimuli, which is in turn modulated by the conditioned reinforcing value of other stimuli present (e.g., the terminal-link chain stimulus).

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Received 24 May 1977.

(Final acceptance 11 November 1977.)